

Advanced neutron spectrometry instrumentation for fusion devices

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The neutron emission from fusion plasmas is a source of valuable information about the state of the plasma fuel ions and the fusion process. The information can be broadly divided into three categories: i) the **neutron flux** gives information about the total neutron emission, and in extension about the fusion power; ii) the poloidally **position resolved emission** gives information about the spatial distribution of the fusion power, and, in DT plasmas, also about the birth profile of the energetic alpha particles; iii) the **energy spectrum** of the neutron emission gives information about details of the distribution function of the fuel ions, such as supra-thermal fuel populations due to neutral beam and/or radio-frequency heating. Different types of instruments are normally used for these categories, with rather “simple” neutron monitors (typically fission chambers) for estimating the total neutron flux, multiple sight line neutron “cameras” to assess the spatially resolved emission, and various types of spectrometers for assessing the neutron energy spectrum.

In this lecture, the focus will be on neutron spectrometry, in particular designed spectrometer instruments. Almost any neutron detector can be used to provide some spectroscopic information, but the quality of the information varies considerably. We will briefly review the nuclear physics basis for neutron measurements, focusing on aspects of relevance for spectroscopy. The possibilities (and challenges) offered by various compact “in-beam” detectors will be reviewed, including organic and in-organic scintillators, and diamonds. However, the main focus will be on the two main lines of designed spectrometer systems, namely, those employing the time-of-flight and thin-foil proton recoil techniques. The physics basis for these instruments will be given, their main designs considerations as well as their challenges and some existing implementations at present-day fusion devices. Some examples will also be provided of the type of information that can be extracted, and of the tools required for the data analysis.